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Effects of stimulus expectancy on heart rate and movement execution

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Some investigations on stimulus expectancy situations have shown decreasing effects of expectancy intervals on heart rate and reaction time, which was interpreted as facilitating effects of such situations. The aim of this study was to find out whether the stimulus expectancy, followed by lower arm movements, would facilitate the execution of movements. Trained subjects executed lower arm movements of different amplitudes, on a kinaesthesiometer, without visual control, after a sound stimulus. Cardiac R-R intervals were continuously recorded during stimulus expectancy, movement execution and resting periods. Results showed cardiac deceleration for all expectancy intervals, but contrary to results of studies on reaction time, no effects of expectancy interval lengths were found on the movement time. This disagreement could be due to task complexities, where the reaction tasks were comparatively simple, while the movement tasks included, not only speed and precision, but also kinaesthetic information processing, which had its effects on sinus arrhythmia, as well.

Parameters of cardiac activity are often used in investigations as indicators of attention, emotional states and task loads in various kinds of tasks. McCloskey (1987) showed that the heart rate does not reflect differences amongst mental tasks of various complexities; heart rate variability parameters seem to be better indicators of changes in mental workload (Atsumi, Sugiura & Kimura, 1993). Murata (1991, 1992) also found that sinus arrhythmia parameters were good indicators of mental workload. Kolisch and Schaefer (1996) pointed out that a decrease in R-R interval variability was a good correlate of changes in mental workload.

Lacey (1972) found that amongst all physiological indicators of activation, pulse frequency and blood pressure were the only ones that could differentiate stimulus expectancy tasks from mental tasks, i. e. the tasks with the cognitive component. According to Lacey's hypothesis, the situations that require stimulus expectancy, which, in fact means concentration and direction of attention to the environmental stimuli, are characterized by a decrease in cardiac frequency. On the contrary, situations that include cognitive component or mental load should result in an increase of cardiac activity.

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Apart from falling heart frequency, the expectancy tasks, signal detection tasks, etc., also cause pupil dilation, GSR (galvanic skin response), and hypertension. These physiological changes in stimulus expectancy situations Lacey interpreted as a higher sensitivity of the organism to external stimuli and readiness for quick and adequate reaction. Namely, it is possible that falling cardiac frequency may be due to reduction in bar receptors activity, as well as to reduction in intensity of neural noise that interferes with information processing.

Since cardiac activity is regulated mainly by the sino-atrial node and parasympathetic activity, the deceleration of cardiac activity is achieved by the vagal parasympathetic suppression on the sino-atrial node.

Deceleration of cardiac frequency in stimulus expectancy situations has been found in many studies (Lacey, 1967, 1972; Koriath & Lindholm, 1986; Obrist, 1974; Takšić & Kunac, 1991; Webb & Obrist, 1970; Jennings, 1992).

In attempts to explain cardiac deceleration in reaction time tasks, which also include stimulus expectancy, several models have been put forward, one of which is Jennings's et al. model (Depascalis, Barry & Sparita, 1995). Their hypothesis is that the pulse deceleration is related to the maintanance of the receptor channel opened and the processor capacity at an adequate level for the task, ready for the processing. The following cardiac acceleration indicates that the processing channel capacity is already engaged in the current mental and motor activities.

During the temporal anticipation, which is present in the time reaction tasks and stimulus expectancy tasks, the efficiency depends on the subjects´ readiness for the stimulus and reaction to it in a given moment. Depascalis, Barry and Sparita (1995) argue that according to this model cardiac frequency deceleration is due to the shift in priorities of selective attention, because the deceleration depends on the awareness of the incoming stimulus.

Some studies have shown that deceleration of cardiac activity in stimulus expectancy tasks has some effects on efficiency parameters in psychomotor tasks that follow after the stimulus, which, in fact, is the signal to start the task. Obrist et al. (1974), Takšić and Kunac (1991) found that simple reaction task time diminished when the expectancy interval increased.

Although in some of these studies simple reaction time tasks were used, the aim of this study was to find out whether cardiac deceleration has got any effects on the efficiency in some more complex tasks such as skilled movement tasks with different expectancy intervals prior to the movement.

Furthermore, as pure movement time of the same movements should be the same, it was reasonable to expect that expectancy intervals could have effects on the kinaesthetic information processing time. This means that these effects could be shown on the residual time between the movement times, when performed with and without visual control, as suggested by Reić and Manenica (2000).

METHOD

Ten well-trained subjects, 20 to 22 years of age performed series of semicircular horizontal lower arm movements with the dominant hand on a kinaesthesiometer, without visual control. The movements differed in amplitudes, which were 20, 40, 60 and 80 degrees. Two different sound signals were used, one of which was pre-signal that indicated the beginning of expectancy interval, while the other meant the start of the movement. The second signal followed 5, 10, 15 or 20 seconds after the first signal, depending on the length of the expectancy period.

As soon as the second signal sounded, the subject had to start the movement, which amplitude was given in advance. Starting of the movement activated the chronometer via a micro switch built in the kinaestesiometer. After the completion of the movement, the subject pressed the micro switch, which he held in his right hand, to stop the chronometer. The total movement time was registered in milliseconds, while the deviation from the given amplitude (error) was read of the kinaesthesiometer scale in degrees. In addition, the subjects preformed the same tasks under visual control, where the movement time was the basis for obtaining the kinaesthetic information processing time for each task separately, when performed without visual control.

The subjects performed the four amplitude tasks four times each. The sequence of the tasks (amplitudes) together with expectancy intervals was arranged according to the Greco-Latin square principles.

During all experimental situations as well as resting periods, subjects´ R-R intervals (heart inter-beat intervals) were continuously measured and recorded via three electrodes and a computerized polygraph.

RESULTS AND DISCUSSION

Although the aim of this study was to find out whether more complex tasks than reaction time tasks have different effects on cardiac activity during expectancy interval, four movement tasks of different complexity (amplitude) showed somewhat different results than those in reaction time studies.

As could be expected, total movement time almost linearly increased as the task complexity (movement ampli-

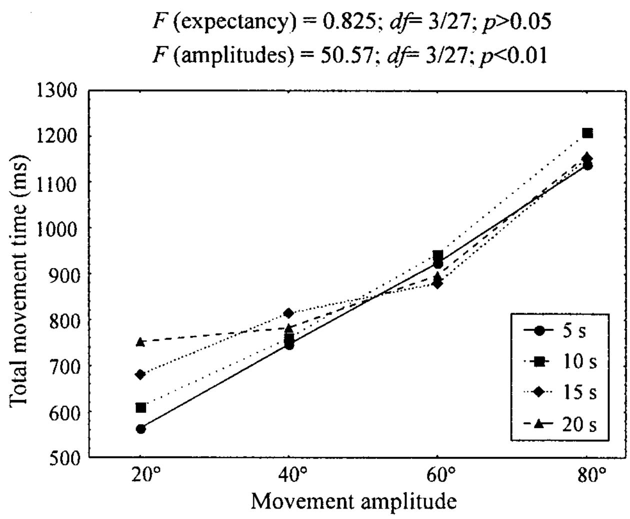

Figure 1. Total movement time after different expectancy intervals

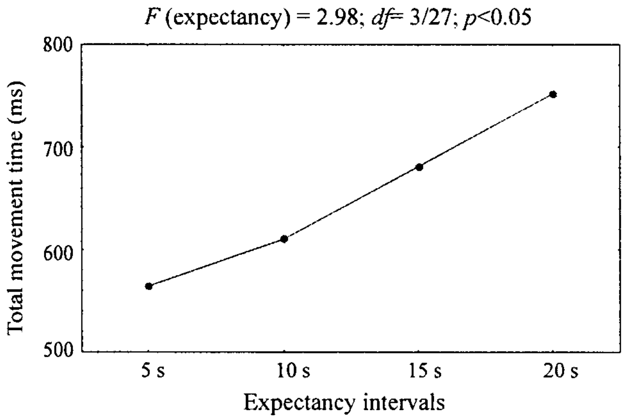

Figure 2. Total movement time after different expectancy intervals for 20° amplitude

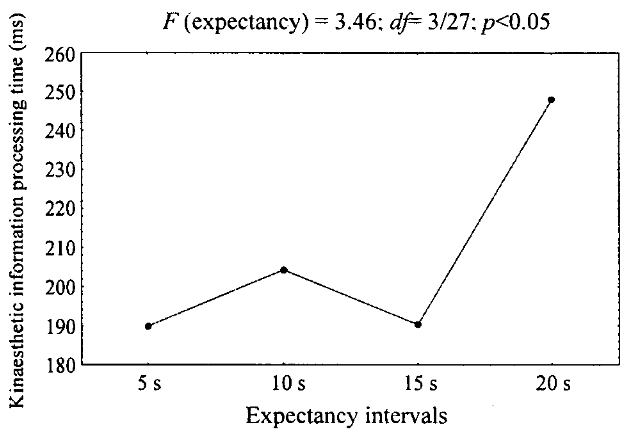

Figure 3. Relationship between expectancy intervals and kinaesthetic information processing time

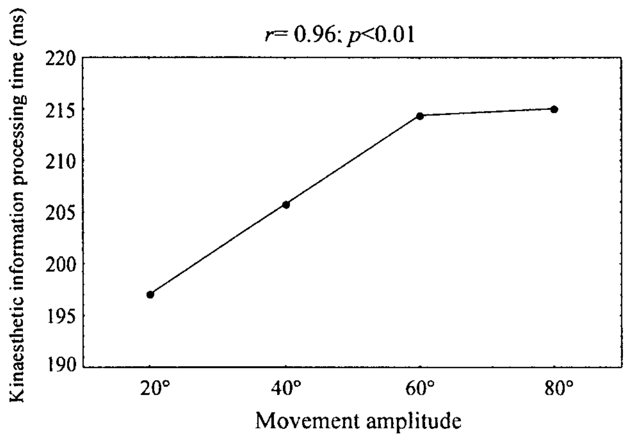

Figure 4. Relationship between movement amplitude and kinaesthetic information processing time

tude) increased, regardless of the expectancy intervals prior to the task (Figure 1).

The only effect of the expectancy intervals on total movement time was observed for the simplest of the four tasks, i.e. 20 degrees movement amplitude. The differences in total movement time amongst four expectancy intervals were significant and linearly increased with the length of expectancy period (Figure 2).

This is in contrast with the results of reaction time studies where the reaction time, generally, decreased as the stimulus expectancy interval increased. Since the movement tasks used in this study were more complex than reaction time tasks, the difference could be attributed to kinaesthetic information processing time, which is a component of the total movement time.

When taken out of the total movement time, kinaesthetic information processing time significantly increased as the expectancy intervals increased. This was less obvious for the intervals up to 15 seconds, but a marked increase was obtained for 20-second expectancy interval (Figure 3).

Since in reaction time tasks the same movement programme is used for all expectancy situations, it is logical to expect the same amount of mental involvement in all the tasks, regardless of the situation. On the contrary, movement tasks, used here, were complex and their complexity (difficulty) depended on movement amplitude. This statement is supported by a high positive relationship between movement amplitude and kinaesthetic information processing time (Figure 4). The correlation was 0.96. As shown in Figure 4, kinaesthetic information processing time increased as the movement amplitude increased, which is logical because movements of bigger amplitude induce more kinaesthetic information and, therefore, require longer processing time.

The results on the relationship between the expectancy intervals and the reaction time in reaction time studies, and the results of this study, are obviously in disagreement. One explanation for these differences is the task complexity, were more complex tasks required much higher subject's concentration (attention) on the task. As the expectancy intervals increased, the subject's concentration might have decreased and the movement that followed required somewhat longer time. Furthermore, one of the factors, which may have contributed to the differences, could also be shorter expectancy interval in most of the reaction time studies, compared with this study.

The analysis of changes in R-R cardiac intervals during expectancy periods showed the expected pattern of chan-

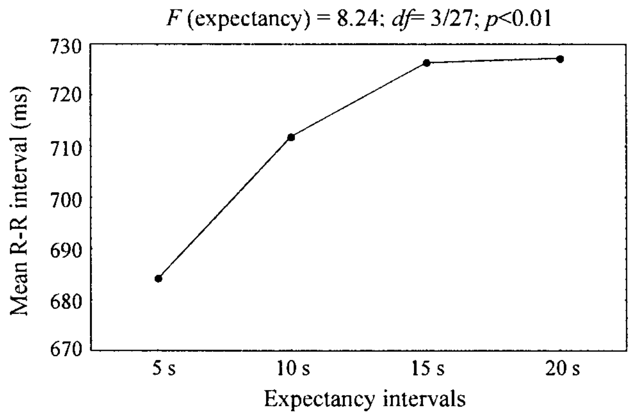

Figure 5. Mean R-R interval during different expectancy intervals

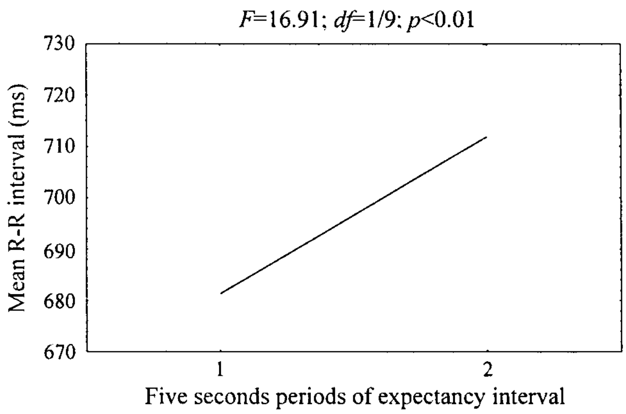

Figure 6. Mean R-R interval for expectancy interval of 10 s

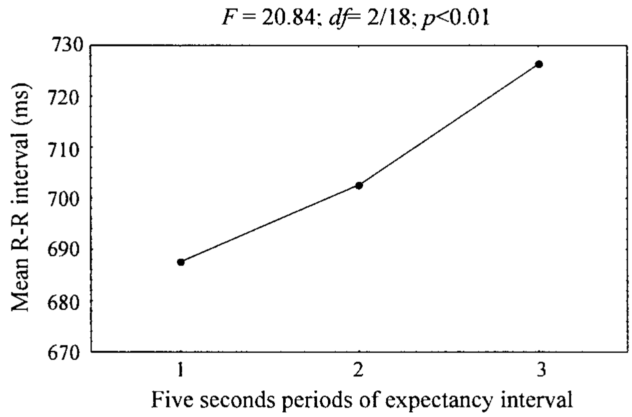

Figure 7. Mean R-R interval for expectancy interval of 15 s

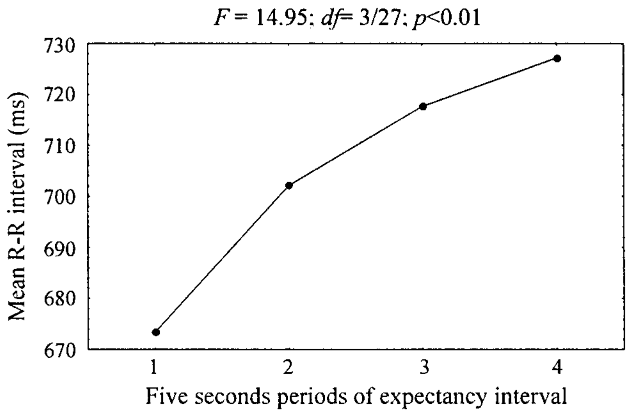

Figure 8. Mean R-R interval for expectancy interval of 20 s

ges, i.e. they increased as the expectancy intervals increased (Figure 5).

Similar results were obtained in a number of studies (Lacey, 1967, 1972; Koriath & Lindholm, 1986; Takšić & Kunac, 1991; Webb & Obrist, 1970, Jennings, 1992). More detailed analysis also showed a gradual increase in R-R intervals during longer expectancy intervals when they were divided into five second periods (Figure 6, Figure 7, Figure 8).

Although the R-R intervals were continuously recorded from the resting period to the end of experimental sessions, the periods of resting, expectancy and movement execution were compared for the magnitude of R-R intervals at equal time points, i.e. 5, 10, 15 and 20 seconds. It was found that they significantly changed during movement expectancy, while no significant changes were found for movement execution and resting periods (Figure 9).

Furthermore, the task complexity, seen as the magnitude of movement amplitude, did not have significant effects on mean R-R intervals ($F(3,27)= 0.42; p>0.05$), but it had a marked effects on heart rate variability ($F(3,27)=16.03; p<0.001$), with a tendency of its decrease as the complexity increased. This is in agreement with many other studies showing a decrease of the variability as the task complexity or mental load increased (Atsumi, Sugiura & Kimura, 1993; Kalsbeek, 1971; Kohlisch & Schafer, 1996; Manenica & Krošnjar, 1990; Murata, 1991, 1992).

These results, as far as the effects of expectancy intervals on cardiac activity are concerned, fit into Lacey's hypothesis, that is that cardiac deceleration seems to be a natural reaction to the focusing of attention to the expected stimulus, when other bodily functions, including cardiac activity, are suppressed. There was, however, no agreement between these results and the results of reaction time studies about the effects of expectancy intervals on task time. The disagreement may be attributed to the differences in task complexities, were significantly higher mental component was present in the movement than in reac-

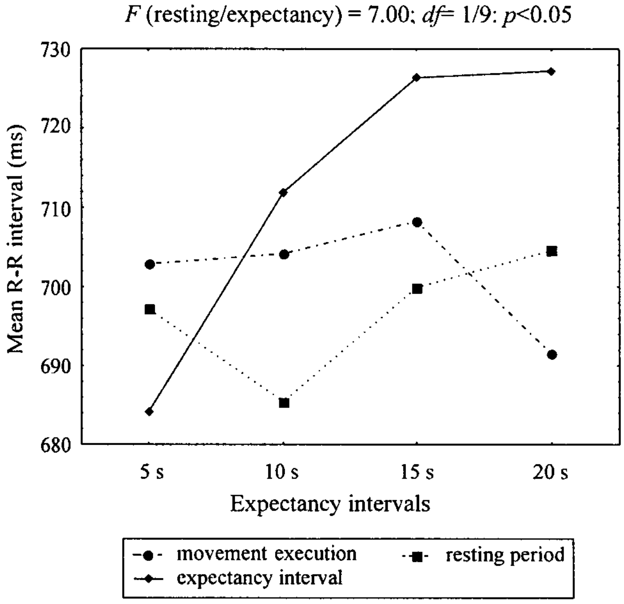

Figure 9. Mean R-R interval during movement execution, resting periods and expectancy for different expectancy intervals

tion time tasks. Magnitude of the mental component seems to have had overcompensating effects on the movement, which is seen in longer movement time. The differences in time between two kinds of tasks are, most probably, due to a higher fluctuation of subject's attention during longer expectancy intervals, which had more significant effects on tasks with a higher mental component.

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